

## EVOLUTION OF THE MURRAY RIVER DURING THE TERTIARY PERIOD. EVIDENCE FROM NORTHERN VICTORIA

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**ABSTRACT:** Contours of the pre-Tertiary surface under the southern Riverine Plain in Victoria show elongated depressions (valleys?) suggesting that a drainage system ancestral to the present Murray system was in existence in Eocene times. The position of the bedrock depressions indicates that in Victoria the basic physiographic divisions and fluvial provinces were established in the early Tertiary and have changed very little since that time.

From Oligocene to early Miocene time it is not possible to demonstrate the presence of a co-ordinated drainage system because the Murray Valley was then probably little more than a swamp. In late Miocene times a co-ordinated system (deep leads) re-appeared and this system flowed into a deep marine embayment in the vicinity of Cohuna in northern Victoria. Aggradation of the deep leads is attributed to rising base levels associated with the onset of the late Tertiary marine transgression.

### INTRODUCTION

Before any meaningful discussion on the Tertiary evolution of the Murray River system it is necessary to consider physiographically, what is the Murray River. For instance we might ask which system during the Eocene would be the Murray River if an upper Murray system consisting of the Murray-Indi, Mitta Mitta and Kiewa Rivers passed northwards to become tributary to the Moulamein-Billabong system while the lower Murray consisting of the Ovens, Goulburn, Campaspe, and Loddon Rivers remain linked as they are today.

Furthermore on a more detailed level it is clear that even in the late Quaternary there have been significant alterations in the course of the Murray River (Pels 1966). Our ability to determine which of the multiple river courses on the surface of the modern plain is the true Murray River depends almost entirely on the capacity to trace, visually, an individual course. Even so, given the tendency for the re-occupation of earlier meander belts by succeeding (and often different) rivers, this is difficult. It becomes virtually impossible when attempting to reconstruct the deeply buried Tertiary river systems.

With this highly dynamic and transient setting it would be pointless to choose a given combination of

river systems at each point in time and to call it the Murray River.

A broader approach must therefore be adopted in which regional physiography, stratigraphy and sedimentation provide a generalized picture of the overall Tertiary drainage system. Thus for the purposes of this paper the broader physiographic province — the Murray Valley (or Plains) is considered a more attainable objective, and the Murray River is defined as the co-ordinated river system occupying the Murray Valley.

### GEOLOGICAL SETTING

Continental sedimentation began in northwest Victoria in Palaeocene times and had extended throughout the Murray Basin by the Eocene (Lawrence & Abele 1976). It has persisted in the eastern parts of the basin up to the present day. In the west, however, paralic sedimentation commenced in late Eocene times and continued until late Oligocene, when the earliest marine sediments are recorded. Marine sedimentation continued until the middle Miocene when the sea retreated from the basin, prior to transgressing again in late Miocene to early Pliocene times before finally retreating (Abele *et al.* 1976).

The two-fold sedimentologic division of the Murray Basin that came into being in late

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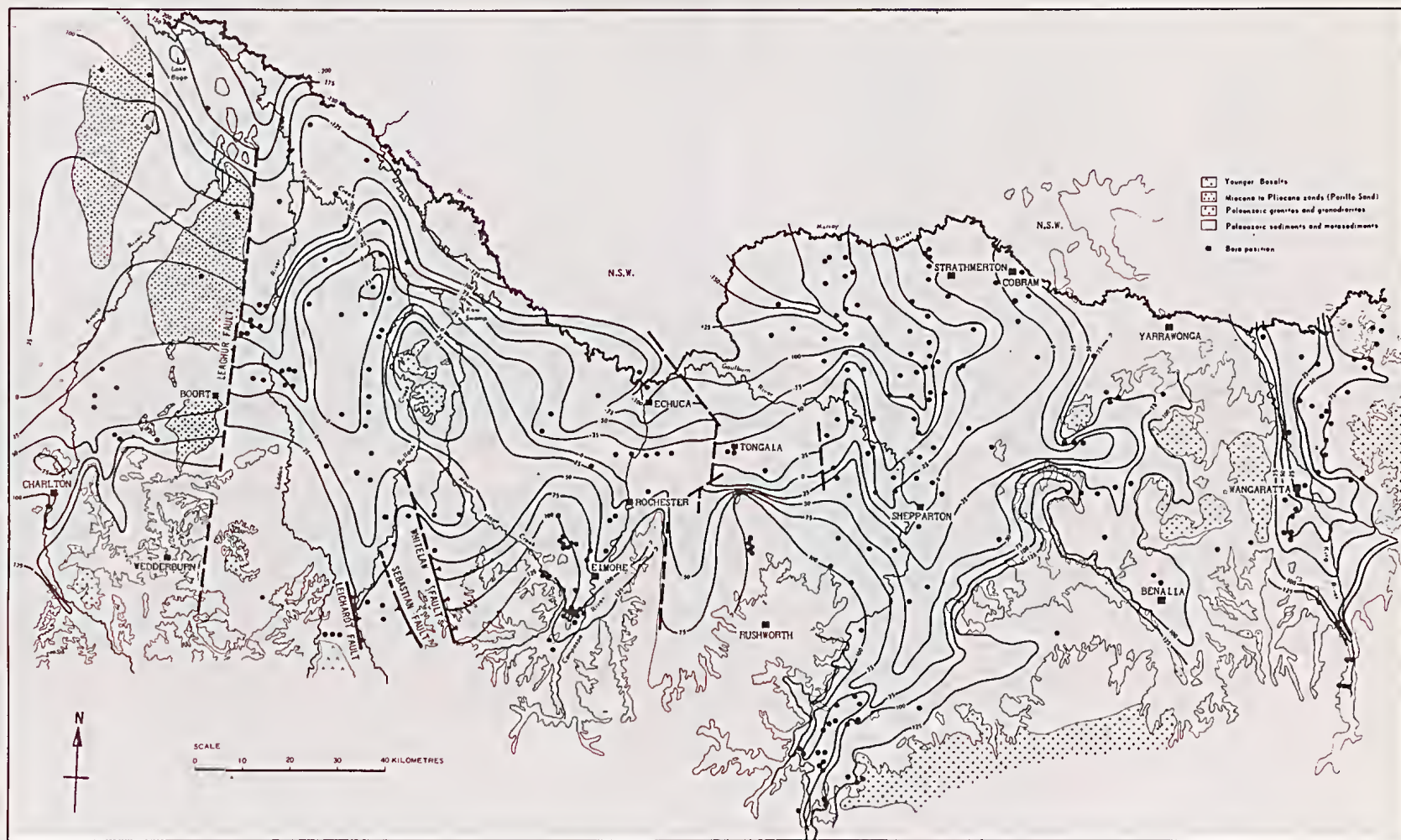


FIG. 1 — Structure contour map of Palaeozoic basement under the southern Riverine Plains in Northern Victoria. (Eastern parts from Tickell 1978.)



Oligocene times persists today, with fluvio-lacustrine sediments being deposited in the eastern (Riverine) parts whilst aeolian sedimentation predominates in the Western (Mallee) area previously covered by the marine transgression.

It is clear that the present day Murray River, upstream of its junction with the Murrumbidgee is essentially a westerly flowing connector linking the northerly and north-westerly flowing (Victorian) tributary systems — passing from the Indi River westwards to the Loddon River.

## EARLY TERTIARY SYSTEMS

Upstream of its junction with the Murrumbidgee the present day Murray River is fed by Victorian streams. It is an east to west flowing trunk system linking the various north flowing tributaries rising in the Victorian highlands. The history of the Murray River is thus directly related to its principal tributaries. During the Eocene the earliest identification of a Murray River is as a fully developed tributary system which passes plainwards from embayments in the highlands, to become at least a partly co-ordinated trunk system further out on the plains.

Structure contours of the pre-Tertiary surface under the southern Riverine Plain in Victoria reveal depressions (valleys) suggesting that a similar drainage pattern directly related to the present system was in existence in early Tertiary times. Early Tertiary valleys can be traced down-basin from the point where the modern river valleys emerge from the highland front, to a position beyond the present day Murray River (Fig. 1).

The position of the valleys indicates that in Victoria the basic physiographic divisions and fluvial provinces were established by Eocene times and have undergone relatively little modification since then. This is consistent with the view of Hills (1934, 1975) who considered that the uplift of the Eastern Highlands had largely occurred by early Tertiary times, and also the work of Wellman (1974) who stated, 'As a result of K-Ar dating of the valley filling (basalt) flows (in eastern Victoria) it has been shown that by the Oligocene the highlands were already in existence and possessed a relief of 1000 m with a drainage system similar to that of present day'. It seems likely that the basal valleys of the Riverine Plain are the downstream extensions of the early Tertiary highland valleys recorded by Wellman and Hills.

It is not known to what extent the basement valleys are erosional and to what extent structural. However it is probable that both factors have been

variously operative. For instance Tickell (1978) notes that the present day distribution of Permian rocks southwards into the Campaspe, Goulburn and Ovens-King valleys suggests that the positions of the valleys were determined to a large degree by the same structures which preserved the Permian rocks. Similarly in the Loddon Valley the confinement of Permian glacial sediments to a narrow band within the highland tract of the Tertiary Loddon River has led the author to conclude (Macumber 1978a) that faulting has played a significant role in the development of the Loddon Valley in late Tertiary times.

The significance of structural control in the continued development and deepening of the basement depressions is well illustrated in the case of the lower Loddon Valley where there is a concordance of levels between the uppermost surface of the Tertiary Renmark Group sediments, deposited within a slowly subsidising graben, and the adjacent stable Palaeozoic surface. This had led to the development of an extensive plain, the Molaga Surface (Macumber 1978b), formed across both Tertiary sediments and peneplaned Palaeozoic sediments. The Molaga Surface has been identified below all of the central Loddon Plains and part of the Campaspe Plains.

The bedrock valleys are overlain (infilled ?) with carbonaceous sediments, the Renmark Group, which range in age from Eocene at the base to middle Miocene at the top (Lawrence 1975, Martin 1977). Sedimentation began with the deposition of a predominantly quartz sand lithofacies (Warina Sand, Lawrence 1975), although gravel, ligneous clays and silts, and minor lignites are present (Figs. 2 & 3). Lawrence noted that when the Warina Sand was deposited the primary control appears to have been the drainage pattern. In some instances the Renmark Group sediments can be traced up into the highland tracts of the valleys. Tickell (1978) notes 'Ligneous clays and gravels which are encountered in the Campaspe and Goulburn valleys . . . can be traced down the valleys and are thought to be continuous with (the Renmark Group)'. The picture is not so clear in the Loddon Valley, because immediately upstream of the highland front, the valley is backfilled with the coarse grained quartz gravels and pebbles, the fluvial 'deep lead' facies of the upper Miocene Calivil Formation (Macumber 1973). If any of the Renmark Group sediments existed they must have been removed from the highland tract by late Tertiary stream activity. It is notable that coarse quartz gravels and pebbles so typical of the Calivil Formation are not a prominent component of the

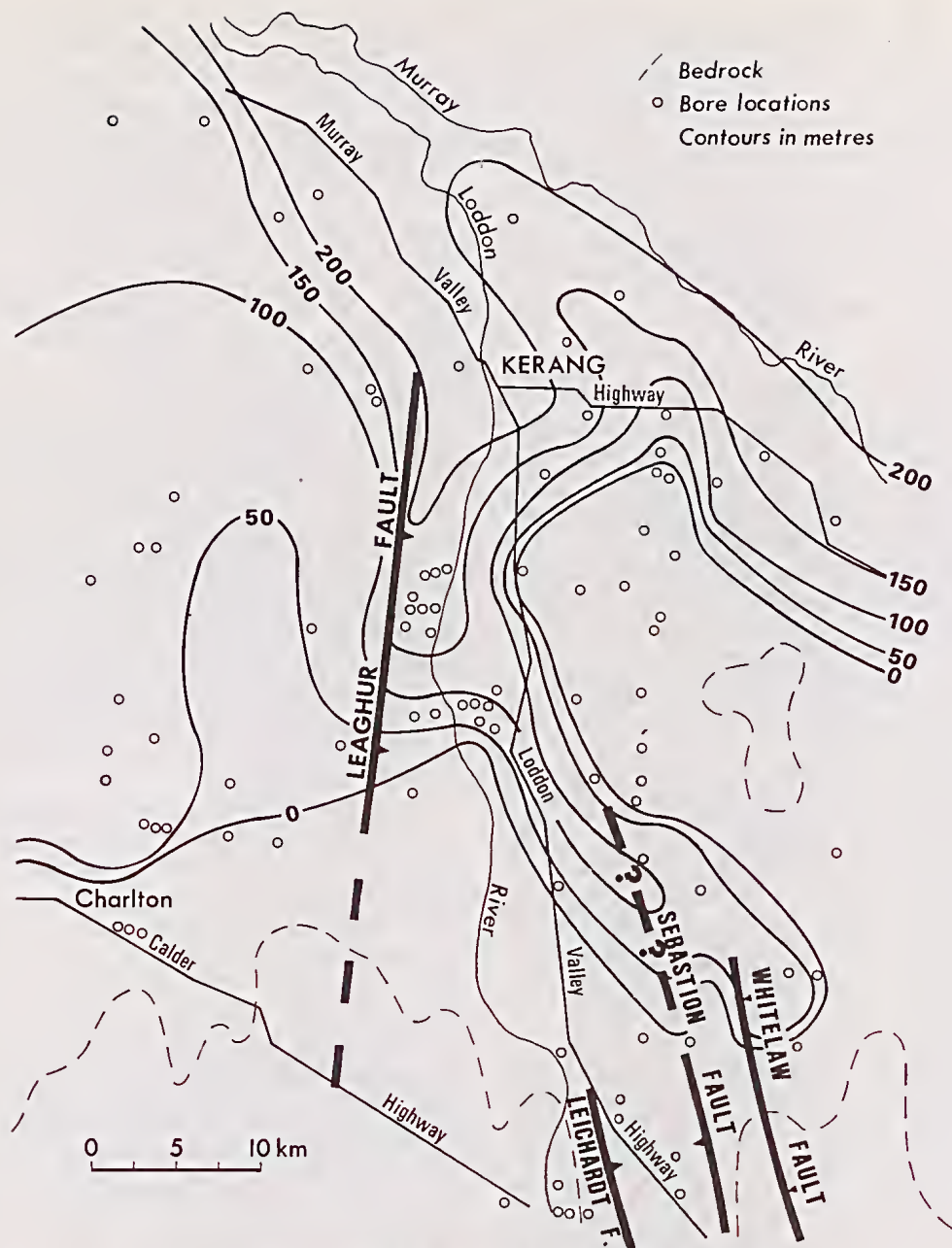


FIG. 2 — Isopach map of the Renmark beds in the Loddon Valley.

sediment infilling the older Tertiary depressions and are usually absent from the sequence.

The investigation of the nature of the down-basin continuation of the early Tertiary systems was restricted by the presence of the State border. However the well-defined character of the tributaries suggests that at least a partly co-ordinated drainage system and therefore a Murray River existed in the eastern Murray Basin in early Tertiary times.

Wherever the Warina Sand is found in the Murray Basin, it is overlain by the Olney Formation (Lawrence 1975) which consists of carbonaceous clay, silt, lignite and sand. Lawrence concludes that the Olney sediments were deposited in deltaic, lagoonal and tidal flat environments. However in the absence of either marine or paralic conditions in the eastern part of the basin, it is concluded that lacustrine and paludal conditions were dominant.



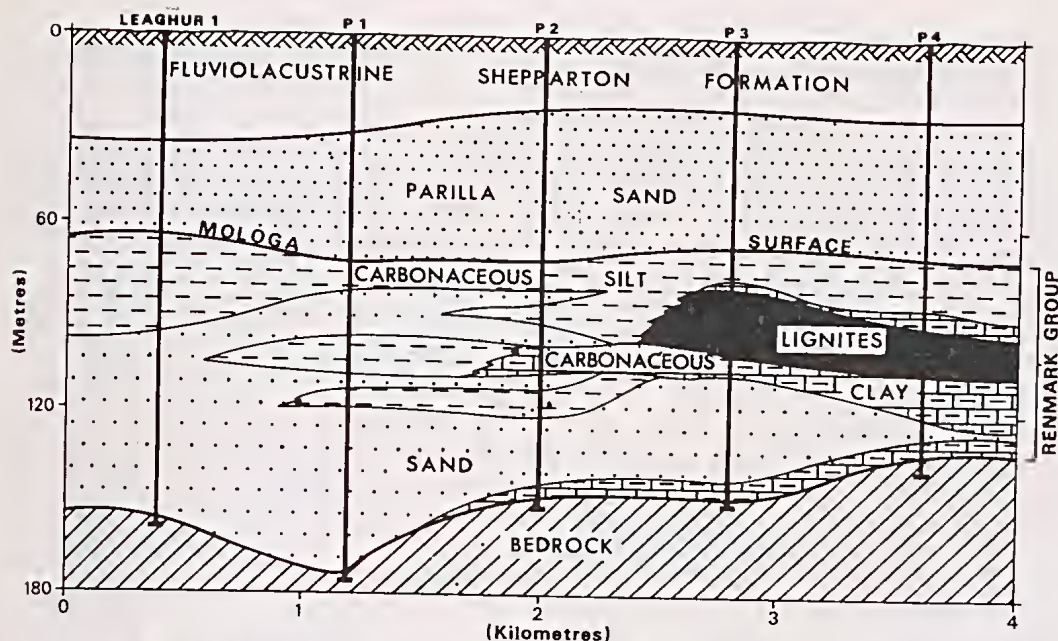


FIG. 3 — Cross section through the western Loddon Plains at Leaghur.

Martin (1977) has placed the upper limits of carbonaceous sedimentation in the eastern part of the Murray Basin as middle Miocene. Martin comments on the latter phases of Renmark Group sedimentation 'This ancient lacustrine landscape is middle Miocene in age and the overlying fluvialite sediments include late Miocene, Pliocene and Pleistocene deposition'. The presence of lagoonal environments close to the highland front indicates a major shift in stream regime whereby the earliest co-ordinated drainage of the Eocene system was replaced by uncoordinated drainage in the Oligocene. These conditions were maintained until middle Miocene times, indicating that during this interval the Murray Valley was essentially an extensive swamp.

#### LATE TERTIARY SYSTEM: THE CALIVIL FORMATION

The late Miocene to early Pliocene drainage system known to the early gold miners as the 'deep leads' is undoubtedly the best documented of the Tertiary river systems (see Hunter 1907). Elements of this system have been traced northwards under the present day Riverine Plain to where they once flowed into a late Tertiary sea which had advanced up the Murray River to Cohuna in the far north of Victoria (Macumber, in press).

A distinctive suite of coarse grained quartz sands and gravels termed the Calivil Formation (Macumber 1973), which was deposited by this system, forms the major aquifer for downbasin

groundwater movement from recharge zones in the Victorian Central Highlands.

Physiographically the various tributary drainage basins which first appeared in the early Tertiary were well established by late Tertiary times and since then these systems have not been further modified to any extent.

Within the highlands the Calivil Formation sediments are confined to the major valleys incised into Palaeozoic basement. However on passing across the plain the Calivil sands and gravel form sheet deposits because the river systems were less confined and hence fanned out (Fig. 4). In the northern areas adjacent to the present day Murray River it is not obvious at which point the individual tributary fluvialite provinces merge into a trunk Murray province. Because of the migratory character of the systems this point could be expected to be fragmented, and therefore an arbitrary line is taken which corresponds to the zone where individual south-north sand tongues merge to make a continuous east-west sand sheet.

Below the Loddon Plains, unconfined fluvial deposits of the Calivil Formation are found only in the south and central parts of the plain, but in the northern areas deposition is restricted to a deep bedrock trench which is an extension of the highland valley. The trench was formed in late Miocene times when a rejuvenated Loddon River cut its course across the middle Miocene Mologa Surface which at that time constituted the Loddon Plain (Macumber 1978b). The trench cuts across

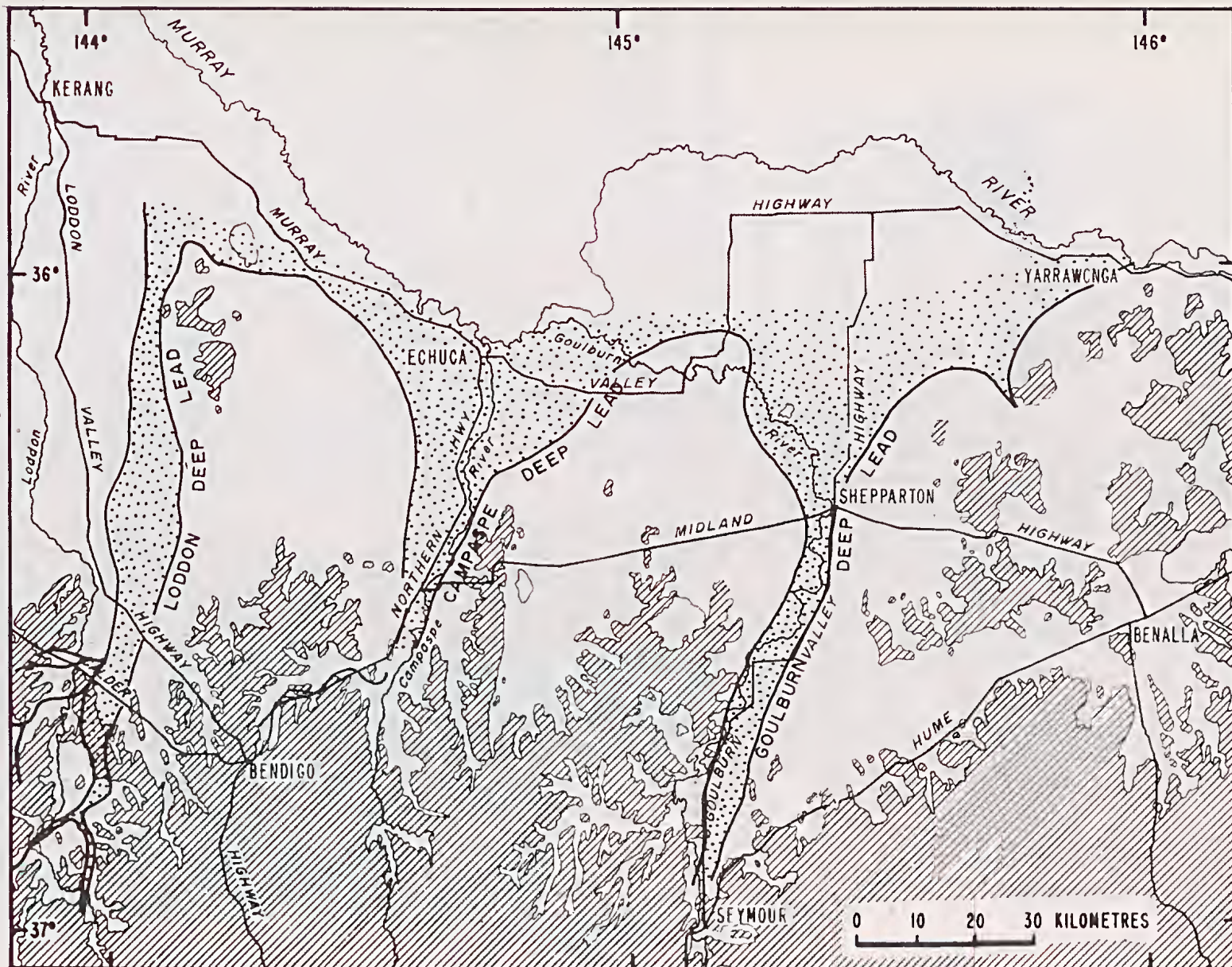


FIG. 4 — Position of the 'Deep Leads' under the Riverine Plain.



both Palaeozoic sediments and Renmark Group sediments (the Olney Formation) before meeting a northwest trending Murray Valley near Cohuna (Fig. 5).

It is notable that the thalweg of the base of the late Tertiary Loddon Valley 'deep lead', from its source on the Divide to its point of junction with the Murray Valley system, has essentially the same gradient as the present day Loddon River. Given the differing physiographic tracts from the Divide to the sea there is a fairly uniform depth of valley fill throughout ranging from about 90 to 120 m in thickness.

This supports Wellman's contention (1974) that the present (late Cainozoic) uplift of the Victorian Highlands may extend only from the southern margin of the highlands to about 40 km north of

the Main Divide. It goes one step further however, in suggesting that there has been no significant uplift of the Victorian Western Highlands since at least late Miocene times.

At its downstream limits the coarse sands and gravels deposited within the trench of the confined Loddon system merge with similar sediments of the ancestral Murray system. In the Gunbower West No. 2 bore drilled 8 km south of Cohuna, sands and gravels occurring from 87 to 107 m are taken to represent deposits of the late Tertiary Murray River system. As is the case in the central Loddon Valley, the gravels overlie fine grained carbonaceous Renmark Group sediments.

The change in fluvial province from the Loddon Valley to the Murray Valley is reflected in an abrupt change in water salinities of the Calivil Formation. In the Loddon Valley salinities gradually increase downbasin, to over 10,000 mg/litre t.d.s. However beyond the junction with the better quality Murray Valley aquifer, salinities of the Calivil Formation fall to 4,000-6,000 mg/litre.

The gravels and sands in the Cohuna-Kerang district are downbasin equivalents to similar sediments found to the southeast in the parishes of Wharparilla and Echuca North.

Downstream, beyond Cohuna, coarse grained channel sediments of the Murray Valley system can be traced in a northwest direction towards Swan Hill. The distribution of bores does not permit the detailed understanding of depositional constraints as is the case for the Loddon Valley but a sharply defined southern limit of the Murray Valley is indicated.

Downstream beyond Cohuna, the Calivil Formation is directly overlain by late Miocene to early Pliocene marine sediments — the Parilla Sand. This unit was originally defined by Firman (1965) in South Australia as a fluviolacustrine deposit, and in Victoria it has been broadened by Lawrence (1976) to include the Victorian equivalents of the marine Loxton Sand of South Australia (Ludbrook 1957). The Parilla Sand was deposited during the short-lived late Miocene to early Pliocene transgression which swept across northwest Victoria.

At its most easterly area of outcrop, on the Gredgwin Ridge west of Kerang, the Parilla Sand consists of cross-bedded fine to coarse grained micaceous quartz sands overlying fossiliferous silts. Heavy mineral bands up to one metre thick are interbedded with the sands.

The upper part of the Parilla Sand has been deeply weathered and poor preservation of the fossils limits their diagnostic and chronologic

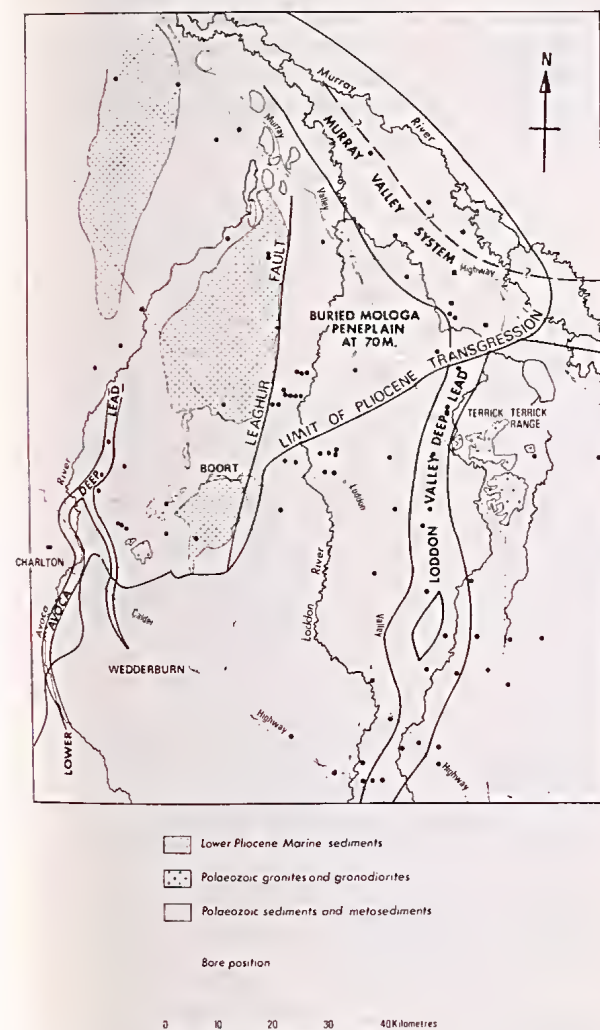


Fig. 5 — Late Tertiary palaeogeography of the Avoca and Loddon Plains in Northern Victoria.

usefulness. In general the bulk of the material consists of mollusca (predominantly pelecypods) including *Dosinia (sensu lato)*, *Gari?* and tellinids. All the valves are disarticulated and crowded convex down along the bedding plains, suggesting a beach or near beach depositional environment. Plant material is also present including complete leaves. The only fossil of diagnostic value so far obtained is the echinoid *Lovenia woodsi* which was found by the author at a quarry 11 km west of Kerang. Elsewhere in Victoria, *Lovenia woodsi* is considered to indicate a late Miocene to early Pliocene age.

Although the Gredgwin Ridge is the Parilla Sand's most easterly outcrop in the Murray Basin, it has been traced eastwards beyond Cohuna under the Quaternary sediments of the Loddon Plains (Macumber 1969). There is no marine sediment in the Wakool bores 36078 and 36102, situated in New South Wales to the north of Cohuna, and the nearest marine sequences recorded in N.S.W. bores are at Balranald about 80 km to the west (Martin

1977). It seems that the sea transgressed up the late Miocene Murray Valley, and at its height, a deep marine embayment covered the lower Loddon Plains, with its most easterly limits passing just inland of the junction of the Loddon and Murray river systems (Fig. 5).

At this stage the Murray Valley downstream from Cohuna was drowned; the lower Loddon and Murray river systems upstream from this point were estuarine. West of Cohuna the Calivil Formation gravels deposited by the Murray River system are directly overlain by, and partly intertongue with, the Kerang Sand Member of the Parilla Sand. In the Kerang area, the Kerang Sand is the basal, transgressive unit in the marine sequence and consists of fine to coarse grained micaceous sands formed in part by re-working of the Calivil Formation. The Kerang Sand is overlain by a clay and silt unit (Tragowel Member) and this in turn is overlain by a predominantly fine grained micaceous sandstone (Wandella Sandstone). This three-fold subdivision of the Parilla Sand is taken to represent



FIG. 6. — Stratigraphic section through the lower Loddon Plains. Lower right, locality plan and isopach map of Parilla Sand.



the form of the transgression-regression cycle at the extreme limits of the transgression up the Murray Valley (Fig. 6).

While the Parilla Sand outcropping on the Gredgwin Ridge is clearly marine, eastwards towards the limits of the transgression deltaic and estuarine elements associated with Murray and Loddon river systems would also be present. No attempt is made to differentiate these various environments. The situation on the Murray Valley system is similar to that described by Taylor (1895) as occurring at Stawell in Western Victoria where marine fossils were found overlying the deep lead sediments at the Welcome Rush, Poverty Hill and Four Post. Taylor commented, 'Before its subsidence below the sea, the original schist country, on which the marine beds were subsequently deposited, was naturally an undulating surface, with its own system of valleys and their tributary branches. They were then filled by the marine drifts, covering the older pre-existing drifts'. He also states, 'The Welcome Rush I believe to have been a fluvial deposit, since covered by a marine deposit'.

The gradually rising base levels that accompanied the transgression led to fluvial aggradation within the Murray and Loddon Valleys. The nature of the aggradation is best illustrated in the Loddon Valley where the late Miocene Loddon River was confined to a deep trench incised thirty metres into the pre-existing middle Miocene Mologa peneplain. The trench was completely backfilled during the transgression and then buried under coastal plain deposits. In general the trench sediments consist of a thick suite of fluvial gravels and sands. In the far north however, closest to the shoreline, the valley is not entirely backfilled with coarse grained deposits but instead the final material is a dense clay valley plug. On passing up-valley the gravel sequence rapidly thickens, and at the highland front is three times its thickness far out on the plain. An explanation for the down-valley wedging of the gravels is seen in the gradual rise in base level of aggradation causing the deposition of finer grained sediments in a gradually retreating flood plain environment developed as a coastal plain. Thus as flood plain environments existed in areas marginal to the advancing sea, coarse valley sedimentation continued uninterrupted up stream beyond the influence of the rising sea level.

Three closely drilled sections across the shoreline show the thick marine sequence as rapidly cutting out to be replaced by flood plain deposits. It seems that the shoreline remained fixed for some con-

siderable time at its eastern limits where a fine balance had been reached between sea level rise and fluvial aggradation.

The sea retreated from the Murray Basin in the Pliocene leaving the Riverine Plain in Victoria as essentially a basin of internal drainage.

## CONCLUSION

Two major phases of valley incision and river development are recognized in the Murray Basin during the Tertiary period. The earliest occurred in Eocene times when a fully developed drainage system passed northwards across the Riverine Plain from highland embayments which are the same as those occupied by present day streams. The Loddon, Campaspe, Goulburn and Ovens river systems were present. The basic physiographic divisions and fluvial provinces of northern Victoria were therefore in existence in the Eocene and have undergone little modification since that time.

A second phase of valley incision and major river development began in upper Miocene times with the establishment of the 'deep lead' drainage system. The Goulburn, Campaspe and Loddon Rivers were tributaries of a trunk Murray Valley system which flowed into a marine embayment near Cohuna in northern Victoria.

Following the marine regression in the early Pliocene the eastern part of the Murray Basin became a basin of internal drainage and remained so until Quaternary times.

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